By complete rest we increase the physiological power of the patient to resist the disease, and, as there is no drug or serum so far discovered which has proved to be a panacea, we are forced to rely on rest, fresh air, good food, and those drugs which we now know limit all inflammatory processes.

In conclusion, we must estimate the amount of advantage to be derived from rest and complete absence of phonation in tuberculosis of the respiratory organs. The violence and amount of cough determines the amount of injury done to these organs and the consequent amount of pyrexia. Every symptom productive of cough is at variance with a return to health. Rest, either partial or complete, should be paramount in all cases.

THE RELATION BETWEEN ANTHRACOSIS AND PULMONARY TUBERCULOSIS.[1]

By Jonathan M. Wainwright, M.D.,
OF SCRANTON, PA.,

AND

Harry J. Nichols, M.A., M.D.,
OF WASHINGTON, D. C.

We all have heard that miners have a tendency to immunity from tuberculosis, that coal dust prevents tuberculosis, and that it even has a curative effect when tuberculosis is once developed. The present article is an inquiry as to whether these ideas have any basis in fact, and if so, what is the cause.

An investigation into the relationship between any disease and an occupation or mode of life is always complex. This complexity becomes more marked when the disease in question is as intricately connected with social, sanitary, economic, racial, and other factors as is pulmonary tuberculosis. It is doubly so when the human factor to be considered is as varied as to race, habits of living, diet, intelligence, etc., as are our anthracite mine-workers.

Some general aspects of the question will to some extent account for a part of the presumed low mortality from tuberculosis among miners. We know now for instance that tuberculosis is essentially a disease of those living under crowded conditions both at home and at their work. Crowding at work is never present among mine-workers. Seldom are there more than two or three and often only one man working in a large chamber. Furthermore, the spread of infection among the men at work is practically impossible as the moisture in the mine prevents the sputum deposited from drying. The germs must either die out from lack of nutriment or be washed away by the mine waters.

---

[1] Read before the Laennec Medical Society, at Baltimore, May 22, 1905.

Conditions above ground also favor a low tuberculous death rate among miners. While in the mining region a far too large number of foreigners will often occupy a small house, there is none of the vast overcrowding of the city tenements. A very large number of miners, at least as compared to many other trades, live with only their own families in separate, single, or double houses. Even the houses overcrowded by foreigners are separate so that the number exposed to infection from a consumptive boarder is comparatively small.

The habits of mine-workers as compared to many other working people also tend in a measure to freedom from tuberculosis. For instance, the mine-worker frequently has to walk several miles to the shaft through the fine air of high altitudes. There is comparatively little travelling to and from work in a sputum-soaked street car. Furthermore, a miner's house being generally on a small lot, his time out of the mines is much more frequently spent out-of-doors than is the case with tenement dwellers. Often some of the time is spent working in a small garden. The fact that a daily full bath is imperative also must have a marked influence on the health of miners.

It is of course a fact that for every trade a large proportion of its tuberculosis mortality belongs really to the saloon. The alcohol factor among miners probably does not differ much from that of other workers of the same social grade. These general factors cannot account for all the difference in mortality from tuberculosis among miners that really seems to exist. It is probable that there are other factors among which anthracosis seems to be important.

Before going farther it will be well to consider what evidence there is that this supposed low mortality among miners is an actual fact. One naturally turns first to statistics. In considering the statistics of a disease like tuberculosis in relation to any occupation it has well been pointed out by Miss Brandt[1] that there are two important factors to be considered as having an influence. One is whether there is for a given occupation a sort of natural selection at work by which only the stronger youths take up the occupation, so that from the start we have a more or less picked class in whom tuberculosis would naturally be rare.

Second, is it a fact that miners who have contracted tuberculosis seek lighter work, and finally, on death, are registered with this second occupation to which they really do not belong, thereby artificially reducing the true death rate among miners and swelling it in another easier trade?

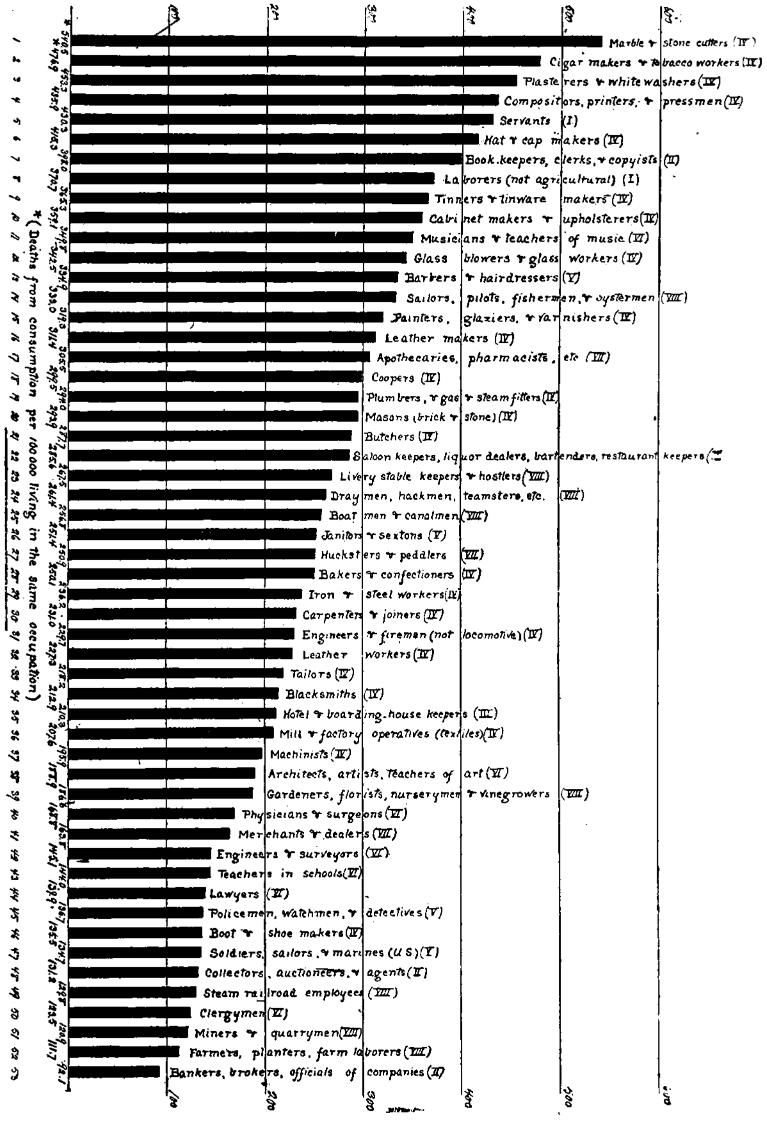
In regard to the first question it does not seem that any one who is at all familiar with coal-mining people will think that the process of natural selection works in any way to make them a picked class. Boys and men take up mining not because they are particularly strong but because it is the easiest work to obtain in the region in which they live, and it becomes in a way their natural destiny.

As to whether weaklings even when admitted to the mining occupations are not weeded out later it may be said that mining is not such a laborious trade as to have this effect. It is certainly not more laborious than that of the farm laborer, with whom they are nearly equal in point of tuberculosis mortality. It is certainly not more laborious than that of blacksmithing, where the mortality is about twice as high.

In regard to the second point, whether consumptive miners do not drift into another trade, it seems that here, too, there is not an appreciable factor. Most consumptives continue at their occupation so long that when they do have to give up they do not have enough strength and ambition left to start a new trade. At death they are registered in the trade which they first followed or among the "unemployed." That the "unemployed" contain many who contracted tuberculosis while in active work is unquestioned, but this factor should not balance in all trades.

We think that Schaffer,[2] of Pottsville, Pa., would have agreed with us that these two factors do not operate in the cases of coal miners. He says of the boy starting to work in the breaker that "He grows up to be a lusty, sinewy youth who seldom troubles doctors except from accident." Schaffer quotes Roy, a mine inspector in Ohio, as follows: "With currents sufficient to carry off noxious gases, smoke, and at least most of the dust, mining becomes not merely a healthy but a pleasant occupation, notwithstanding what has been said about its drawbacks . . . men who go from the farm and shops to work for a season in the mines rarely go back to their old work."

The largest collection of statistics bearing on this matter is probably that of the United States Census for 1900. In classifying deaths according to occupations it is unfortunate that the census bureau groups all miners and quarrymen together. On this account it is impossible to get for the whole United States accurate figures concerning coal-miners alone. However, it is to be remembered that all authorities consider colliers the healthiest class of miners, and all agree that stone-dust is much more injurious than coal-dust. It is therefore unquestionably true that the figures for coal-miners alone would be more favorable than those for all miners and quarrymen combined. The following comparison of this class, then, must be read with the knowledge that the comparison for coal-miners alone would be more favorable still. In the census classification from the registration area of fifty-three occupations for the census year 1900, miners and quarrymen occupy the second place from the bottom in point of view of tuberculosis mortality. The two classes which have a lower mortality rate are: (1) farmers, planters, and farm laborers, and (2) bankers, brokers, and officials



of companies. The rate of death for miners and quarrymen per 100,000 living in the occupation is 120.9. Comparing this with a few of the presumably more healthful occupations we see the rate for lawyers is 139.9, for physicians and surgeons 168.8, for carpenters and joiners, 231.0; for draymen, hackmen, and teamsters, 261.4; for sailors, pilots, and fishermen, 333.1, etc. The highest in the list are marble-cutters and stone-cutters at 540.5. The rate for out-door laborers, in which miners are grouped, is 147. These statistics are graphically shown in the accompanying diagram, reproduced from the *Handbook on the Prevention of Consumption*, through the courtesy of Miss Lillian Brandt.

According to the same census report consumption caused 10.6 per cent. of all deaths among miners and quarrymen, as against 16.2 per cent. for all occupied males, and as against 10.2 per cent. for the out-door group, among which miners are included.

In the whole United States consumption caused 9.6 per cent. of all deaths among miners and quarrymen as against 14.5 per cent. for all occupied males, and as against 11.2 per cent. for the out-door group of workers. (The figures for miners and quarrymen are based on a return of 5895 total deaths from all causes.) According to this table, therefore, consumption is nearly one-third less frequent among miners and quarrymen than among other occupied males. As noted above, the rate for miners alone would be still less.

In England statistics point equally strongly to a diminished mortality from tuberculosis among miners. Tatham[3] presents a very succinct statement of the case based on figures from the Registrar-General's office for 1890 to 1892. These English statistics show that the relative figures for deaths from phthisis among coal-miners is only 97 as against 109 for all classes of miners (iron, copper, tin, lead, etc.), as against 115 for farm laborers and 185 for all occupied males.

Parry,[4] from English figures on more or less dusty occupations gives the following table of relative mortality in which coal-miners stand lowest not only in regard to consumption but also in regard to all other diseases of the lungs. In both respects they stand lower than all occupied males.

TABLE I.—PARRY (ENGLAND).

	Relative mortality figures.		
Occupations.	Consumption.	Other diseases of lungs.	Total lung diseases.
Coal-miners	126	202	328
Carpenters and joiners	204	133	337
Plumbers, painters, and glaziers	246	185	431
Masons, builders, and bricklayers	252	201	453
Wool manufacturers	257	205	462
Cotton manufacturers	272	271	543
Quarrymen, stone and slate workers	308	274	582
Cutlers	371	389	760
Filemakers	433	350	783
Earthenware makers	473	645	1118
Cornish (tin) miners	690	485	1148
All males, England and Wales	220	182	402

(Sweeps, coal-heavers, and trimmers are given higher figures than coal-miners.

We have not been able to find any large collection of French or German statistics.

In order to get some first-hand information in regard to our own anthracite mine-workers, as a class, we have gone over the death certificates on file at the Scranton Bureau of Health for ten years and have worked out the percentage of deaths from various causes, the average length of life, etc., among miners as compared with other occupied males. The years covered were the last ten, excluding 1902, the year of the long strike of over five months. A short strike of a little over a month in 1900 was ignored. With a general population of something over 100,000, Scranton has had during the above period 857 deaths among miners and 2656 deaths among other occupied males. In each case the actual certificate of the physician furnished data and only complete certificates were used.

Aside from the ever-present possibility of mistaken diagnosis, there are two special circumstances which make our results suggestive rather than mathematically absolute. In the first place, many certificates were excluded as incomplete, and a slight error may have crept in from this. It is fair to assume that this exclusion affects both groups to the same degree. Secondly, the occupation in many certificates is only given as laborers and it was possible that some mine laborers were so designated. On going over the certificates we came to regard this possibility of error as slight because mining is such a distinctive occupation that we found special reference made to it, or the context showed the exact occupation. With these qualifications our statistics are as follows:

TABLE II.—SHOWING PERCENTAGE OF ALL DEATHS WHICH ARE CAUSED BY VARIOUS LUNG DISEASES AND TRAUMA (FOR LAST TEN YEARS AT SCRANTON).

	Pulmonary tuberculosis.	Asthma.	Pneumonia.	All lung diseases.	Trauma.
Anthracite mine-workers (857 deaths)	3.37 %	7.0 %	10.96 %	23.45 %	45.57 %
All other occcupied males at Scranton (2656 deaths)	9.97 %	1.58 %	13.85 %	27.86 %	14.15 %

Taking the percentage of deaths from all lung diseases among miners as 100 the relation is as follows:

TABLE III.

	All lung diseases.	Pulmonary tuberculosis.	Asthma.	Pneumonia.
Anthracite mine-workers	100	14	29	42
All other occupied males	114	41	7	54

From our own figures in Scranton it would seem that tuberculosis is about two-thirds less frequent among miners than among all other occupied males. By taking our figures of 3.3 per cent. as the proportion of all deaths among miners due to tuberculosis and comparing it with the census figures for the whole United States we get the following table:

TABLE IV.

	Percentage of all deaths due to consumption.
Anthracite mine-workers	3.3 %
Miners and quarrymen, whole United States	9.6 "
Out-door laborers, " " "	11.2 "
All occupied males " " "	14.5 "

So far as statistics go, we will rest here. It will be of interest to note, however, that the average age at death in anthracite mine-workers from all causes is 42.89 years as against 46.36 years for all other occupied males in the same city. The average age at death from trauma is 34.15 years among the miners and 36.05 among all other occupied males. From causes other than trauma the average age at death is 49.93 for miners as against 48.05 for other occupied males. In other words, if we exclude trauma miners live slightly longer than all the other occupied males in the same city.

Now, we will examine the opinions of writers who have paid special attention to the hygiene of mining or other occupations. As early as 1863 Kubon,[5] of France, says that "coal-dust is unable to cause pulmonary tuberculosis or even to favor the evolution of pre-existing tubercles. It prevents the development of phthisis."

De Crocq,[6] Belgium, in 1862 said that several physicians had noted the rarity of consumption among coal-miners.

In Germany, Arnold[7] says: "It has been noted that among miners tuberculous diseases are very rare. It has even been considered that there is an antagonism between anthracosis and tuberculosis." Arnold disclaims any personal experience in the matter, but considers that if there is any action it is due to the fact that the deposits of dust prevent the spread of the poison. He does not believe that there is a direct action of the dust on the bacteria.

Seltman, quoted by Burger,[8] found tuberculosis a rare disease both in old and young miners. He also announced that coal-dust exerts a favorable influence on a tuberculous process already present. He says that many physicians have treated tuberculosis of the lungs by the inhalation of coal-dust.

Goldman[9] says that tuberculosis is a rare disease among coal-miners. He says it causes only 1 per cent. of deaths among them. This he attributes to an antiseptic action of the dust. Goldman quotes Hirt, who in 4000 cases of pulmonary tuberculosis found that 22 per cent. had been subject to various kinds of dust, 11 per cent. had not been subject to dust, and only 1 per cent. had been subject to coal-dust. Goldman says that tuberculosis is more prevalent among miners' families than among miners themselves. Basing our opinion on a service of over four years in a large miners' hospital, and also on a somewhat close study of the tuberculosis problem in the largest anthracite centre in the United States (Scranton) we most decidedly agree with Goldman in this statement.

Dirksen,[10] Germany, says that coal-workers have the best health of all dusty occupations. He says that in Upper Silesia only 0.9 per cent. of all internal diseases among coal-miners are due to tuberculosis. He says that many claim a direct immunity from tuberculosis in coal-miners.

In England, Oliver,[11] of Newcastle-upon-Tyne, who is one of the greatest authorities on occupational diseases, draws a sharp line between lesions due to dust and those due to tubercle bacilli. He does not give much attention to the relative action of one on the other. He does say, however, that "ventilation of the British coal-pits has practically abolished pulmonary consumption among our miners."

Trotter,[12] of Beddingtonshire, an English coal-field, says: "As a disease, phthisis is probably more uncommon among coal-miners than among any other class of workers. . . . I am inclined to believe that the comparative rarity of phthisis among coal-miners is probably largely due to the protective influence of coal-dust or soot." He considers this partly a mechanical action due to the coal-dust and soot clinging to and covering the sharp angles of the mineral matter inhaled and "to a lesser degree to an antiseptic and deodorant action." He says that "the death returns from phthisis in a colliery district show a greater proportion of deaths among females than among males." (See Goldman's and our own opinion above.) "Colliery surgeons almost invariably state that phthisis is not so common among miners as in other districts in which they have practised."

We have been trying to add some experimental evidence to the question of the influence of anthracosis on tuberculosis, and as far as we have gone our experiments have been affirmative. Our method has been to keep guinea-pigs about two months in a box in which coal-dust is constantly stirred up. In this way quite a degree of anthracosis has been produced. We have then taken these pigs and injected a suspension of a pure culture of tubercle bacilli directly into the trachea which was exposed by dissection. In this way one can be quite sure that the tubercle bacilli actually reach the lungs. Control animals which had not been subjected to the dust were also injected in the same way with the same syringe full of suspension so that as far as possible the same dose was obtained for all. In the first series when the pigs were killed the control had extensive tuberculosis of the lungs and abdominal viscera. The anthracotic pig had extensive tuberculosis of the abdominal viscera and of the glands around the tracheal injection, but *the lungs were free.* In the second series the result was the same. Two anthracotic pigs were injected and the lungs of both were free. In the third series the two anthracotic pigs had pulmonary tubercles, and practically the post-mortem finding did not differ from the control of the series. If, therefore, half of the pigs were protected from pulmonary tuberculosis by the coal-dust it creates a strong argument. It is not of course to be presumed that every pig would be protected. The animals thus far tested are too few to be completely conclusive, but a great deal of time will be required to get more data. The conclusion of each experimental series takes about four months. Many series have had mishaps and failed, so that many months have been lost. These experiments are being continued.

We have also obtained a similar result by injecting a suspension of coal-dust into the testicles of guinea-pigs, and later injecting the testicles with a suspension of tubercle bacilli. Pigs which had previously been injected with coal-dust lived on an average forty-nine days. The controls lived on an average twenty-five days.

Having gone as far as is now possible in demonstrating that those who have anthracotic lungs are less susceptible to tuberculosis the cause of this phenomena must be considered.

The most frequently mentioned theory is that it is due to the germicidal action of the coal-dust. We have tested the germicidal action of coal-dust by various methods on tubercle and typhoid bacilli, staphylococcus, vibrio, and several unidentified bacteria, and have found that the dust has no germicidal action whatever. It is true that if bacteria are mixed with sterile dust and allowed to remain in contact with it in a test-tube for several days and then plated a slight inhibitory influence will be observed, but even this prolonged close contact will not kill bacteria. There are also several *a priori* reasons against this germicidal action of the dust.

Dr. Nichols considers that it is possible that the soluble calcium salts which form a large proportion of the ash of coal-dust may at least play a part in the protective influence. He is now working on his theory.

Another idea has been that the rarity of tuberculosis among miners is not due to any protective influence but depends on the fact that the air of mines is comparatively free from bacteria. We have shown by tests that in the air of the chambers this is the case. The air supplied to chambers passes slowly through damp gangways sometimes a half-mile. During this passage many bacteria fall to the ground so that the air when supplied to the chambers has undergone a purification by sedimentation just as takes place in rivers. Our tests were by the ordinary Petri-dish method. The dishes being exposed at the beginning of the intake or air tunnel and again for the same length of time in various chambers. The following are two characteristic examples of results:

TABLE V.—SHOWING THE PURIFICATION OF AIR BY PASSAGE THROUGH INTAKE.

	Number of colonies on dish in three minutes.	
	Diamond mine.	Dodge mine.
Beginning of intake	880	390
Average in chambers	54	18
End of return tunnel	15	

That this bacterial purification of the air in which the miners work, together with the fact noted above that tuberculous sputum cannot dry, must have some effect in diminishing tuberculosis cannot well be doubted.

As we have said, however, it is probably not the sole factor. Our own opinion is that the coal-dust in the lungs does exert a real protective influence against the tubercle bacilli, and that it is due to the stimulating effect of the coal-dust on connective-tissue growth. This connective-tissue growth is of course the way in which nature overcomes the tubercle bacilli and anything which stimulates it will be a valuable aid in preventing the bacilli from getting a foothold or in overcoming them when once established.

That the coal dust causes this stimulation of connective-tissue growth is well known. Microscopically, anthracosis may be divided into three stages.

The first is seen in those who have worked in the mines only a few months. In these some of the epithelial cells lining the alveolæ can be seen to be swollen and to contain coal-dust. Sometimes a few larger desquamated cells containing much pigment can be found in the alveolæ, lying loose with some detritus and free dust particles. Even in the early stage dust particles can be seen in the walls of the air vesicles and around the bronchi. In this stage there is no thickening.

The second stage occurs in those who have worked in the mines for several years. In these cases the swollen epithelial cells containing dust particles are much more numerous. The alveolæ contain more detritus consisting of swollen, dust-bearing, epithelial cells, and free dust, and some leukocytes. The pigment in the walls of the air vesicles is more marked. It collects particularly in the connective-tissue septa between lobules, where it is in such large masses as to be easily seen by the naked eye in microscopic sections. These are especially well seen in the septa that run in from the pleura and one will frequently see considerable-sized black triangles with their bases on the pleura showing where some septum has been completely filled up with dust. With this deposit there goes an increase in the connective tissue of the alveolar septa wherever there is much dust. The interlobular septa thicken as does also the peribronchial connective tissue, as here also the dust tends especially to collect. With this stage the bronchial and mediastinal lymph glands are enlarged and perfectly black. The glands in the lesser omentum are also frequently black from dust swallowed in the saliva. This increase of connective tissue is almost never sufficient to give signs of consolidation. With this stage sometimes comes the condition misnamed "miner's asthma." This is really a chronic bronchitis and emphysema both in symptoms and physical signs.

A third interesting picture is seen in those who have formely been miners for many years but who have not been in the mines for some years before death. In these the signs of irritated swollen epithelium have subsided. The epithelium is again normal and neither the cells nor the alveolæ contain dust. The deposits of dust in the alveolar walls, the septa and the peribronchial tissue still remain and there is the same connective-tissue thickening.

This histological picture of epithelial irritation and connective-tissue thickening with consequent loss of elasticity of the air vesicles easily accounts for the condition inaccurately termed "miner's asthma." This is clinically a chronic bronchitis and emphysema. We had formerly considered that the simple anthracosis could never give rise to physical signs of consolidation. Quite recently, however, we have seen an old miner who had distinct signs of consolidation down to the fourth rib on the right side. There had been no history of acute inflammation nor of tuberculosis. Repeated sputum examinations and the tuberculin test were negative and we were forced to conclude that the signs of consolidation were due to anthracosis. In some fifteen autopsies on miners we have never seen any diffuse consolidation. Only once have we made out tuberculous scars at the apices. Though these can easily be concealed in the blackened lung.

"Miner's phthisis," which is an unfortunate term used in England, is undoubtedly a misnomer as far as the phthisis goes. Real tuberculous lesions in miners are always due to the tubercle bacillus.

It may be of interest to note in passing merely as a matter of record that we have made a number of analyses of miners' lungs and those of people who are not anthracotic. By the most careful methods we could employ we found that there was a considerable margin of error. In a rough way we can say that the foreign matter in the lungs of old miners is about 33 per cent. of the dried lung. In adults who have not been especially subject to dust it runs from 1 to 3 per cent. or a little over.

The quantitative estimation of the dust in mines may also be of interest. This quantity naturally varies with many conditions. The average of twenty-five different determinations of the dust in mines which we have taken is 0.0354 gram per cubic metre. The screen-rooms in the breakers were much more dusty, giving an average of 0.3967 gram per cubic metre.

The only other quantitative determination of the amount of coal-dust in mines which we have seen in literature is that of Hesse, quoted by Dirksen,[10] as 0.0143 gram per cubic metre of air.

A comparison of the quantity of dust in the air in mines with that in other places can be seen in the following table complied by Dirksen:

TABLE VI.—AMOUNTS OF AIR IN VARIOUS PLACES.

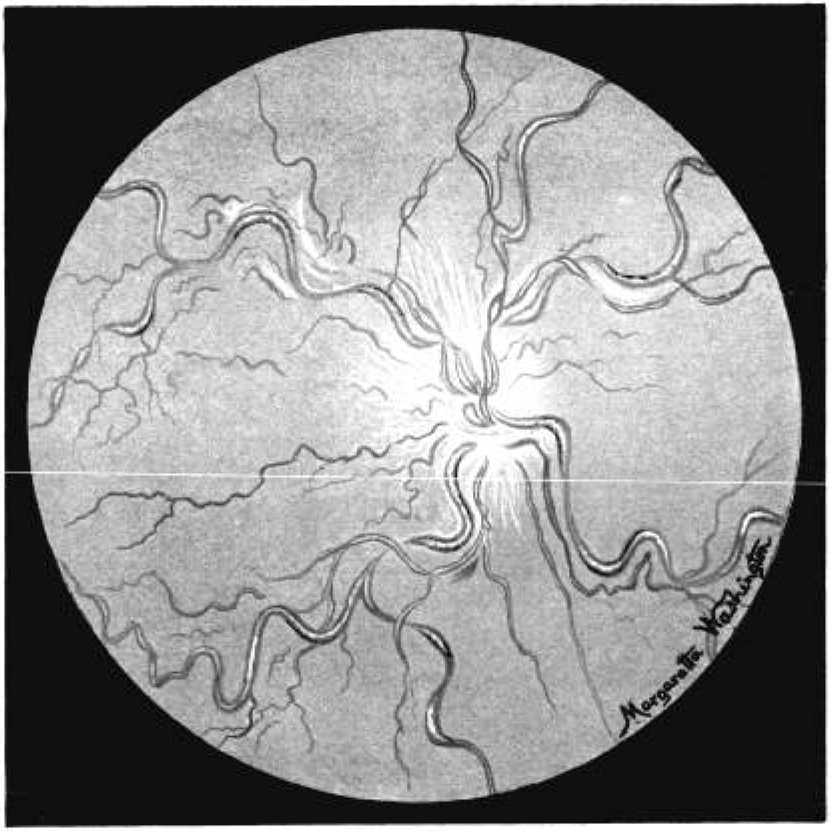
	Observer.	Grams per cubic metre.
City after rain	Tissandier	0.00025
Iron foundry	Arens	0.0015–0.0280
Iron foundry	Hesse	0.0717
Saw mill	Arens	0.0150–0.170
Snuff factory	Arens	0.0160–0.0720
Grinding mill	Arens	0.028
Grinding mill	Hesse	0.047
Cement factory	Arens	0.13–0.224
Felt slipper factory	Arens	0.175
Bunker on steamship	Dirksen	0.0828–2.2897
Coal-mine	Hesse	0.0143
Coal-mine (average)	Wainright and Nichols	0.0354
Coal-breakers (average)	Wainright and Nichols	0.396

From this table it will be seen that there are a number of places as dusty as modern coal-mines. There are few places dustier than the screen-rooms of breakers.

In concluding, we wish to thank Professor Mendel, of Yale, and Professor Abbott, of the University of Pennsylvania, and Dr. Sweet, of the Rockefeller Institute, for many valuable suggestions. And the latter also for placing at our disposal facilities of the Hygiene Laboratory, where a part of our experimental work was carried on, the other portion being done in the laboratory of the Moses Taylor Hospital at Scranton.

BIBLIOGRAPHY.

1. Hand-book on the Prevention of Tuberculosis, Charity Organization, New York, 1903.
2. Schaffer. Hygiene of Coal Mines, Ziemssen's Encyclopedia, 1871.
3. In Oliver's Dangerous Trades, London, 1902.
4. Parry. Risks and Dangers of Various Occupations, London, 1900.
5. Kubon. Du Role Pathologique des pousser dans les organes respiratoire des ouvies des mineurs, Bull. de l'acad. de med., Belgique, 1863.
6. De Crocq. De l'anthracose pulmonaire, ibid., 1862.
7. Arnold. Untersuchungen über Staub inhalation und Staub metastasen, Leipsic, 1885.
8. Bürger. Der beziehungen der tuberculose zu der anthracose, Marburg, 1903.
9. Goldman. Die Hygiene des Bergmannes, Halle, 1903.
10. Dirksen. Quantitative Staub bestimmungen der luft der Kohlen bunker, Archives für Hygiene, 1903, No. 11.
11. Oliver. Miner's Phthisis, British Medical Journal, September 12, 1903.
12. Trotter. The So-called Anthracosis and Phthisis in Coal-miners, British Medical Journal, May 23, 1903.
13. Hanna. Ueber der Kohlegehalt des menschlichen Lungen, Archives f. Hygiene, vol. xxx. p. 835.



Cyanosis Retinæ.